be connected by a line of steamers plying between Hawaii and Salina Cruz.

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SPECIAL ARTICLES.

THE PRIMEVAL ATMOSPHERE.

THE geological import of certain chemical work[1] carried out at the University of Heidelberg by Professor Krafft and his students seems to have been overlooked.

Krafft has determined for a number of metals the lowest temperatures at which they evaporate in a nearly perfect vacuum. He estimates the vacuum obtained as having a pressure of less than one millionth of an atmosphere. In order to avoid all action of gravity the evaporation temperatures were determined in a tube (1 to 1.5 cm. diameter) placed horizontally.

He has also determined the boiling points in vacuum of the metals, *i. e.,* the temperature it is necessary to reach to force a steady 'saturated' stream of vapor upwards from the liquid against the force of gravity.

In boiling under ordinary pressure it is necessary to force the stream of vapor upwards against gravity *plus* the atmospheric pressure.

Krafft finds that it requires the same number of degrees rise, within the limit of error of the experiment, to pass from the temperature at which evaporation in a vacuum begins to the temperature at which boiling in a vacuum occurs as to pass from the latter temperature to the temperature at which boiling at atmospheric pressure (760 mm.) occurs.

In other words, that the same rise of temperature is required to overcome the force of gravity at the earth's surface as to overcome the atmospheric pressure and from this the conclusion is drawn that gravity and atmospheric pressure are equivalent.

Krafft's experimental data are given in the following table, also the differences between the temperatures of the beginning of evaporation and boiling in a vacuum (Differences I.) and between boiling in a vacuum and boiling at atmospheric pressure (Differences II.).

Element.	Evaporation Begins in a Vacuum (0 mm.).	Differences I.	Boiling Occurs in a Vacuum (0 mm.).	Differences II.	Boiling at Atmospheric Pressure (760 mm.).
Mercury....	— 40°	195°	155°	202°	357°
Cadmium..	156	294	450	299	749
Zinc	184	366	550	370	920
Potassium.	63	302	365	302	667
Sodium.....	98	320	418	324	742
Bismuth...	270	723	993	707	1700
Silver	680	680	1360	680	2040
		2,880°		2,884°	

It will be noted that, whether a metal of low boiling point or one of high boiling point is taken, the two differences are for any given element very nearly the same. The lack of exact agreement is probably largely due to the experimental difficulty of measuring some of the temperatures.

The writer wishes to direct attention to the bearing of the above on the question of the character of the primeval atmosphere and on the theories of world formation.

The atmosphere is held about the earth by the action of gravity and from the above we are forced to the conclusion that the mass of the atmosphere is as great as gravity is able to control. Perhaps this will be made clearer by the crude comparison of the interaction of the earth and the atmosphere to that of a rotating bar magnet and its iron filings.

The magnet is capable of exerting a certain attractive force. When the filings are present in full amount, *i. e.,* when the magnet can hold no more filings, the attractive force of the magnet for the filings is exactly equal to the attraction of the filings for the magnet. If a less amount of filings were present the attractive force of the magnet would be greater than the attractive force exerted by the filings. If a larger amount of filings were placed in contact with the magnet a certain amount, the 'full amount' mentioned above, would be held and the rest would be thrown off, *i. e.,* the attractive force exerted by the iron filings

[1] *Ber. d. chem. Ges.,* XXXVI. (1903), pp. 1,690 and 4,344; XXXVIII. (1905), pp. 242, 254 and 262. A brief review of the work is given by Professor Renouf, *Am. Chem. Jour.,* XXXIII. (1905), p. 506.

is never greater than that exerted by the magnet.

In the case of the earth and its atmosphere Krafft has given us our first measurement of the attractive force of the earth (gravity) and the attractive force of the atmosphere for the earth (atmospheric pressure) in the same unit of measurement (degrees of heat). His measurements show that the two are equal and we must, therefore, conclude that the present atmosphere of the earth is the largest it is capable of holding. If from any source additions were made to our atmosphere a corresponding amount would be thrown off, *i. e.*, escape from the atmosphere into space. The portion thrown off would probably consist of those molecules having the highest molecular velocities lying in the upper strata of the atmosphere.[2]

The various theories of world formation all give gravity a smaller value in the past than it has at present. There is yet to be found the first evidence tending to show that gravity has ever been greater than at present. If gravity has never been greater than at present then from Krafft's results we must conclude that the atmosphere of the earth can never have been greater than the present atmosphere and the atmospheric pressure never greater than 760 mm. of mercury (14.7 pounds).

We here find ourselves in decided disagreement with the Laplacian hypothesis commonly accepted by geologists and astronomers. Geikie[3] says: "It is certain that the present gaseous and liquid envelopes of the planet form only a portion of the original mass of gas and water with which the globe was invested. Fully half the outer shell or crust of the earth consists of oxygen, which probably once existed in the primeval atmosphere."

Dana,[4] in discussing the subdivisions of Archæan time, gives perhaps the best statement of the prevalent view:

> The astral æon, as it has been called, or that of the fluid globe having a heavy vaporous envelope containing the future water of the globe or its dissociated elements and other heavy vapors or gases. * * * The lithic era: commencing with earth as a solid globe, or at least solid at the surface; the temperature at the beginning above 2,500° F.; the atmosphere still containing all the water of the globe (amounting to 200 atmospheres, according to Mallet,[5] 1880), all the carbonic acid now in the limestone and that corresponding to the carbon now in the carbonaceous substances and organic substances (probably 50 atmospheres), all the oxygen since shut up in the rocks by oxidation, as well as that of the atmosphere and of organic tissues.

Other calculations of the primeval atmosphere give it the same or even a greater extent, *e. g.*, Prestwich[6] by a calculation later than Mallet's reaches the same value for the water vapor. T. Sterry Hunt[7] finds the carbonic acid alone 200 times the present atmosphere.

A small primeval atmosphere is just as much out of harmony with the idea of the formation of the globe by the contraction of a quasi-gaseous swarm of meteorites, as suggested by Lockyer and by Darwin,[8] and with all other hypotheses requiring for the earth at any time a surface temperature above that of boiling water, as it is with the Laplacian hypothesis. It is, however, in excellent agreement with the planetesimal hypothesis developed by Chamberlin and Moulton,[9] in which

[2] Compare the articles on the conditions of the escape of gases from the atmosphere, by G. Johnstone Stoney, in which he has shown that the molecular velocities of hydrogen and helium are so large that the earth is unable to retain them in its atmosphere. *Trans. Royal Dublin Soc.*, 1892, p. 563; *ibid.*, 1897, p. 305. *Astrophys Jour.*, VIII. (1898), 316; XI. (1900), 251 and 357; XII. (1900), 201.

[3] 'Text-book of Geology,' 4th ed., Vol. I., p. 34.

[4] 'Manual of Geology,' 4th ed., p. 440.

[5] *Quart. Jour. Geol. Soc.*, XXXVI., p. 112.

[6] 'Geology,' Oxford, 1886, Vol. I., p. 417.

[7] Brit. Assoc. Rep., 1878, Trans., Sec. C, p. 544.

[8] Compare Darwin's classic paper, 'On the Mechanical Condition of a Swarm of Meteorites and on the Theories of Cosmogony,' *Trans. Phil. Soc.*, 1888.

[9] Best presented by Dr. Chamberlin in 'Fundamental Problems of Geology,' Year Book No. 3 (1905) of the Carnegie Institution of Washington, pp. 195–258. Compare also Chamberlin, *Jour. Geol.*, V. (1897), p. 653; VIII. (1900), p. 58; IX. (1901), p. 369; Moulton, *Astrophys. Jour.*, XI. (1900), p. 103; Chamberlin and Moulton, SCIENCE, XII. (1900), p. 201.

they show the possibility of a building up of the earth and the present solar system by the gradual accumulation of small bodies. The investigations by Lunn in connection with the study of the planetesimal hypothesis have shown[10] that the probable progressive condensation of the earth under the influence of gravity is sufficient to account for the heat requirements of past geologic ages as well as the present high temperature of the interior of the earth.

It is generally held that the warm and moist climate of the Carboniferous and Tertiary eras was due to an atmosphere much more dense and of much greater extent than the present atmosphere. According to the high authority of Dr. Svante Arrhenius it is not necessary to make such a supposition. An analysis[11] of Langley's experiments gave data showing that the competence of carbon dioxide to retain solar heat is so great that its addition to the extent of only one tenth of one per cent. of the present atmosphere would give us a climate like that of the Tertiary era and that the removal of one fiftieth of one per cent. would bring on glaciation. By later and somewhat more exact experiments of his own Arrhenius[12] obtained results indicating that the percentage changes of carbon dioxide would have to be slightly greater than those calculated from Langley's experiments. We must conclude that our present atmosphere, with but very slight variations, would account for the great changes of climate that have occurred in past geologic ages.

The immense deposits of limestone and coal[13] have been taken to imply a primeval atmosphere containing large amounts of carbon dioxide. Closer examination[14] has shown that it is much more probable that the deposition of limestone and coal has been periodic, as if the atmosphere had been alternately enriched and depleted of carbon dioxide. As a source of carbon dioxide T. Sterry Hunt[15] has suggested that it has been received by the earth, from time to time, through the fall or near contact of meteorites, since small amounts of carbon compounds are found in these bodies. The planetesimal hypothesis considers the earth as largely formed from bodies of the general character of the meteorites that reach the earth's surface. Concerning the competency of these to furnish the gases of the atmosphere no better can be done than to quote Dr. Chamberlin:[16]

> Meteorites carry on the average several times their volume of condensed gas; so do many, probably most, igneous rocks of the earth. * * * Atmospheric material is carried into the earth's body by them to-day in quantities that are large relative to their masses. * * * The gases chiefly occluded in meteorites and the crystalline rocks are hydrogen, carbon dioxide and carbon monoxide in leading amounts, and marsh gas and nitrogen in small amounts. The atmospheric material thus condensed within the growing earth could become part of the atmospheric envelope only by extrusion. * * * It may be assumed that the internal gases were given off progressively and fed the atmosphere.

That the planetesimals were quantitatively sufficient to furnish the gases necessary to supply the earth's water and atmosphere, including the carbon dioxide which has at different stages been taken from the atmosphere, will now be shown. The water and atmosphere[17] at present about the globe are estimated to be about 1/5,000 of the earth's mass.[18] If water be considered as formed by the action of hydrogen on ferric oxide, as there is experimental ground for believing provided the

[10] To be published by the Carnegie Institution of Washington.

[11] *Phil. Mag.*, S. 5, XLI. (1896), p. 237.

[12] 'Kosmische Physik,' II. (1903), p. 503.

[13] The coal deposits while large in themselves are insignificant in comparison with the limestone. The total coal corresponds to less than four tenths of one per cent. of the carbon contained in the limestone. See Dana, 'Manual of Geology,' 4th ed., p. 485.

[14] Compare 'The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere,' T. C. Chamberlin, *Jour. Geol.*, VI. (1898), p. 609.

[15] *Loc. cit.*

[16] Year Book No. 3, Carnegie Institution of Washington, p. 236.

[17] The mass of the atmosphere is but 1/200 of that of the water and in the present rough calculations may be entirely omitted.

[18] Chamberlin, *Jour. Geol.*, V. (1897), p. 673.

right temperature and pressure are present, then, as hydrogen is but one ninth of water, the amount of hydrogen used to form the water of the earth would be 1/45,000 of the mass of the earth. If we add the amount of carbon dioxide which went to form limestone and carbonaceous substances[19] we will add one fourth the amount of the water, *i. e.*, 1/20,000 of the mass of the earth. The sum of these, 1/14,000 of the mass of the earth, will be the amount of gas which has been driven out from the original material by pressure and heat, and which is now represented by our present water and atmosphere and the carbon dioxide which has been from time to time withdrawn from the latter. If the planetesimals had on an average a density of three, this being the density of the average rock of the earth's surface, and contained on an average two times (Chamberlin above says 'several times') their own volume of gas of the average density of water vapor, then the amount of gaseous substances mentioned above (1/14,000 of the mass of the earth) would be about one seventh of the mass of the gas contained by the planetesimals from which the earth was formed. This may be shown as follows: An average gram of material contained in a planetesimal would contain two thirds of a cubic centimeter of gas (density taken as 18/32 of that of oxygen), weighing .00051 gram at 15°. If it gave off only the amount mentioned above, 1/14,000 of its mass, it would give .00007 gram, which is about one seventh of .00051 gram, the amount it is capable of giving off.

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[19] Dana, *loc. cit.*

CURRENT NOTES ON METEOROLOGY.

TEMPERATURES IN CYCLONES AND ANTICYCLONES.

IN the Archives of the Imperial Academy of Sciences of St. Petersburg for June, 1905, of which a reprint has lately been received, Mr. A. Lawrence Rotch reported upon the results obtained by means of kites at Blue Hill Observatory regarding the temperature of the free air in cyclones and anticyclones. Thirty-four ascents showed a vertical decrease of temperature in cyclones and anticyclones at a much lower rate than the adiabatic rate of cooling in ascending air, and also showed almost the same rate of decrease in low and high pressure areas up to 3,000 meters. In view of this latter fact, as Teisserenc de Bort pointed out, the temperature of these two columns of air, up to height of say 4,000 meters, depends to a large extent on the season and upon geographical conditions, as well as upon the relative position of the pressure system. The thirty-four cases were distributed equally among cyclones and anticyclones, and among different seasons. Yet the mean sea-level temperature at a mean pressure of 29.646 ins. was 48.4°, and at 30.157 ins. the temperature was 48°. The following table summarizes the results.

	Meters Above Sea Level.							Mean.
	0	500	1,000	1,500	2,000	2,500	3,000	0 — 3,000
Mean Pressure 29.646″, Temp.	48.4°	44.2°	39.2°	34.3°	31.5°	28.0°	22.6°	35.4°
Mean Pressure 30.157″, Temp.	48°	43.7°	38.7°	35.2°	31.3°	27.1°	21.7°	35.1°

A better method, first used by Mr. Clayton in connection with kite ascents in 1899 and 1900, is to determine the temperatures at the same heights for several days in succession while changes of pressure and temperature are taking place at the earth's surface. By this method it was found that the maximum temperature at all heights up to about 4,000 meters nearly coincided with the minimum pressure at sea level, but was somewhat ahead of it, and that the minimum temperature at all heights coincided with a sea-level pressure above normal, but preceded the latter at a considerable distance.

A LABORATORY MANUAL.

A VERY convenient form of laboratory notebook is found in Professor Frank W. Darling's 'A Laboratory Manual in Physical Geography' (Atkinson, Mentzer & Grover, Chicago and Boston, 1905). All teachers who